Luminous Flux Calibration of LEDs at NIST

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The luminous flux (unit, lumen) is one of the most important characteristics of Light Emitting Diodes (LEDs) along with the luminous intensity, and is commonly measured using integrating sphere photometers. However, large variations of measurement results are reported among different manufacturers and users of LEDs, which is causing difficulties in trade. CIE 127 [1] gave a good solution to the problems in luminous intensity measurements, but does not give sufficient treatment for the problems in luminous flux measurement. There are issues such as the LED mounting geometry (4π, 2π), treatment of backward emission, the best integrating sphere geometries, etc., which are being addressed in CIE Technical Committee 2-45. While these issues are to be resolved, there is an urgent need for standard LEDs in order to certify measurement accuracy in industrial laboratories. To address such needs, NIST has developed measurement procedures to calibrate total luminous flux of LEDs using the existing NIST 2.5 m integrating sphere [2].

Figure 1 shows the arrangement of the NIST integrating sphere for LED measurement. This arrangement is for integration over 4p – the normal definition of total luminous flux – therefore including the backward emission. The LED is mounted on the center of the sphere, aiming at the azimuth angle ***q*** = 130°, illuminating the portion of the sphere wall where the spatial nonuniformity of the sphere response is minimum. The LED is mounted using a special LED mount, as shown in Fig. 2, to minimize the near-field absorption around the test LED. The baffle (normally 20 cm) in front of the photometer head is replaced by one with a 10 cm diameter in order to reduce the area of shadowed region and thus minimize the spatial nonuniformity errors [3]. Other sphere

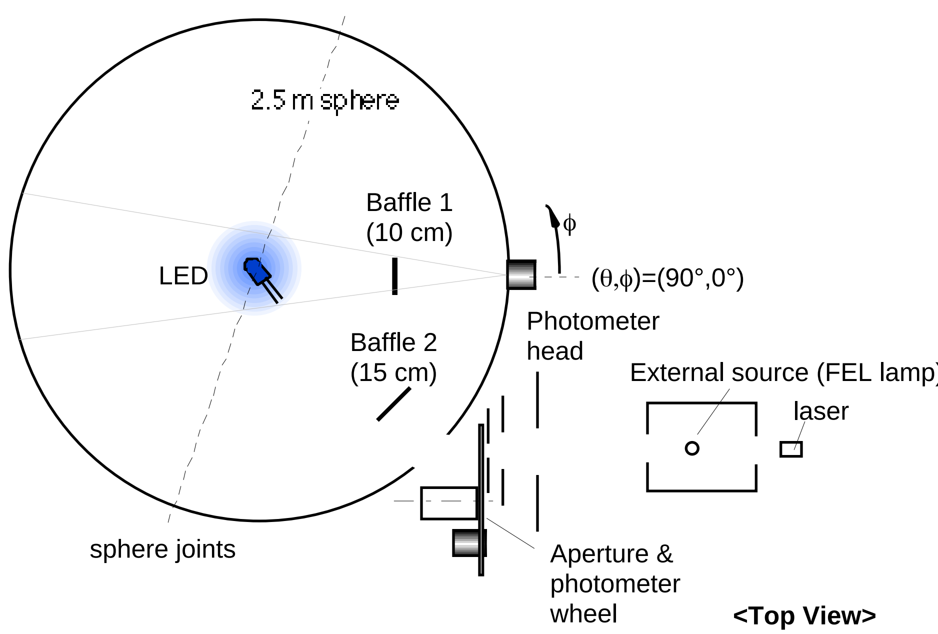

Figure 1. NIST integrating sphere system arranged for calibration of LED total luminous flux.

arrangements remain the same as the normal configuration for calibration of lamps. The test LED is measured using our detector-based method [2] in comparison with the beam flux introduced from the external source, which is approximately 2 lm. In spite of the size of the sphere, we have enough signals for typical high-intensity LEDs having luminous flux of 0.1 lm to 1 lm, in part to the high reflectance (~98 %) of the coating. The photometer head is a temperature-monitored type with a built-in amplifier having gain ranges up to 10^9 V/A.

Figure 2. The LED mount in the sphere.

The spectral mismatch correction is applied by measuring the spectral power distribution of each test LED and the total spectral responsivity of the sphere system. The measurement uncertainty arising from the spatial nonuniformity of the sphere response has been analyzed for this particular sphere geometry using the measured spatial response distribution function (SRDF) and an LED model with a variable beam angles (Fig.3). Figure 4 shows the calculated correction factors with respect to an isotropic point source, as a function of the LED beam angle. The measurement errors, if not corrected, are shown to be within 0.15 % for beam angles from 20° to 120° (Lambertian), which is taken into account in the uncertainty budget. The calibration service for luminous flux of limited types of LEDs is now available at NIST. The expanded uncertainty (***k***=2) of the calibration is from 0.6 % to 2 % depending on the color and other characteristics of the reference LEDs. A dedicated integrating sphere system for LED measurements and standard LEDs for luminous flux are to be developed.

References

[1] CIE Publication No. 127, Measurement of LEDs (1997).

[2] Y. Ohno and Y. Zong, "Detector-Based Integrating Sphere Photometry," Proceedings, 24th Session of the CIE Vol. 1, Part 1, 155-160 (1999).

[3] Y. Ohno and R. O. Daubach, "Integrating Sphere Simulation on Spatial Nonuniformity Errors in Luminous Flux Measurement", ***J. IES***, Winter 2001 issue (to be published).

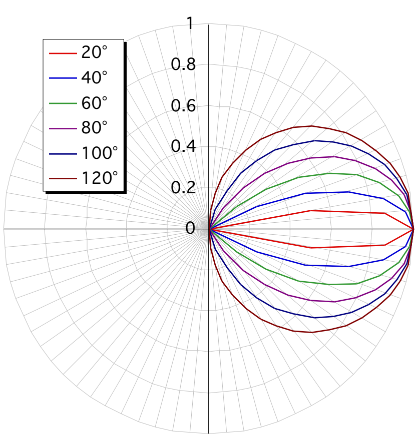

Figure 3. LED model of varied beam angle.

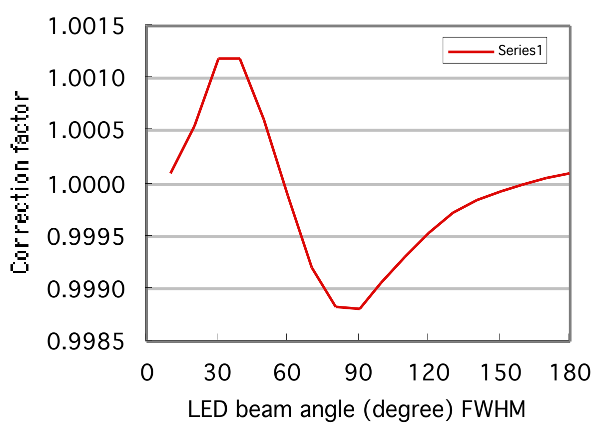

Figure 4. Correction factor for the spatial nonuniformity of the sphere, for an LED model of varied beam angle.